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INT CL^7 H04B 1/10 17/00 , H04L 12/24 12/28 , H04Q 3/00 7/34 7/36
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(54) Abstract Title
Determining a quality of a frequency reuse plan in a communication system

(57) A communication system (201) implements an intelligent optimization system (IOS) block (200) to improve system quality in accordance with the invention. Measurement reports performed by a mobile station (222) are transferred to the IOS block (200) via E1 links (212) as is configuration information in the form of C/I values from an operations and maintenance center (OMC 215). This information is used by the IOS block (200) to determine a frequency reuse plan using at least one penalty value. The frequency reuse plan has associated therewith a quality factor (QOS) related to a proportion of estimated communication system traffic which is expected to experience poor quality due to the determined frequency reuse plan. If the frequency reuse plan is acceptable, the IOS block (200) passes relevant information to the OMC (215) which implements the plan.

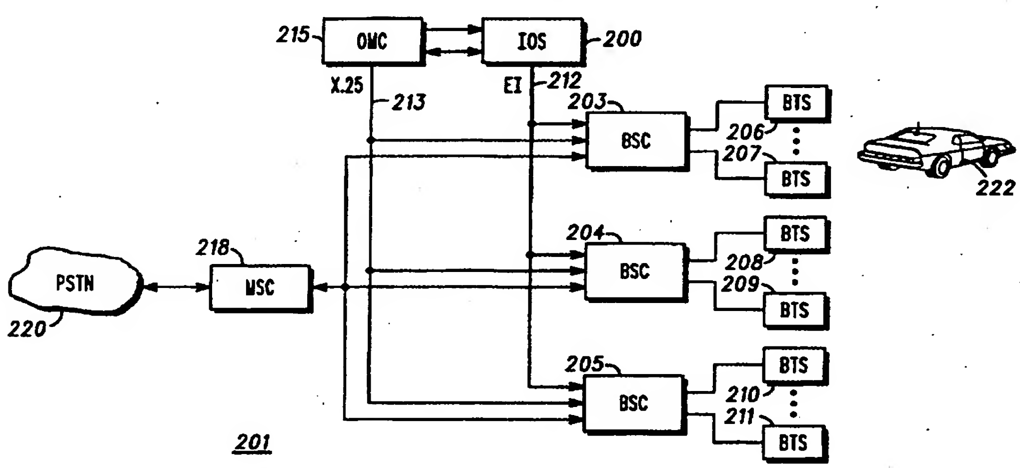


FIG. 2

GB 2 356 320 A

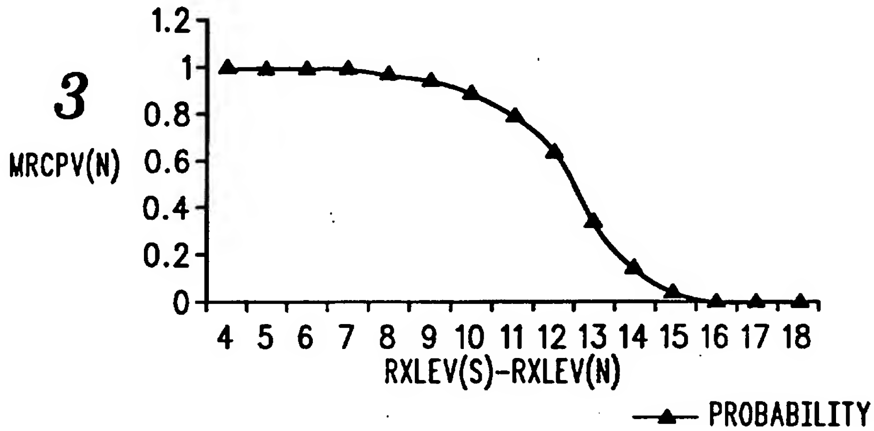
At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

	A	B	C	D
A		15	5	$\boxed{10}$
B	10		4	8
C	5	20		17
D	$\boxed{7}$	30	5	

TOTAL PENALTY=10+7=17

FIG. 1

FIG. 3



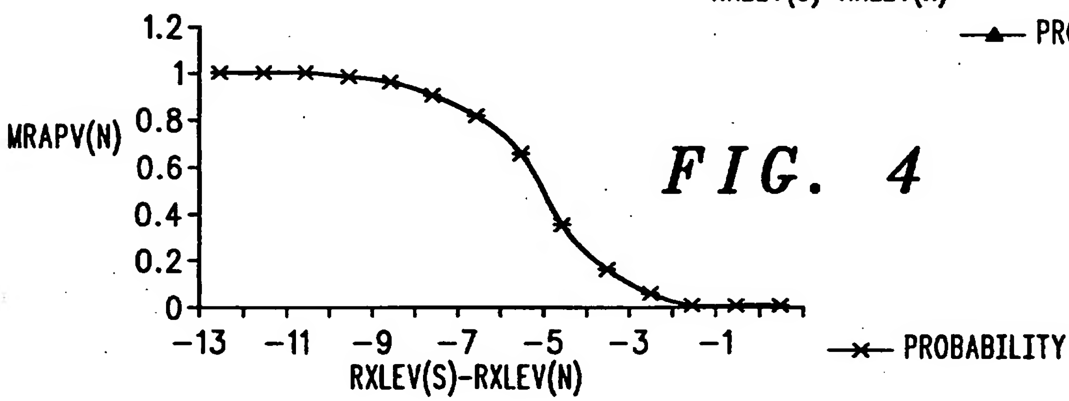
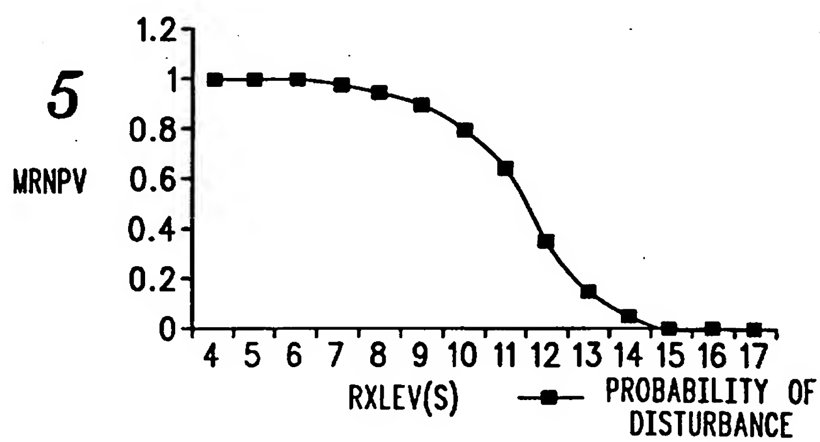


FIG. 4

FIG. 5



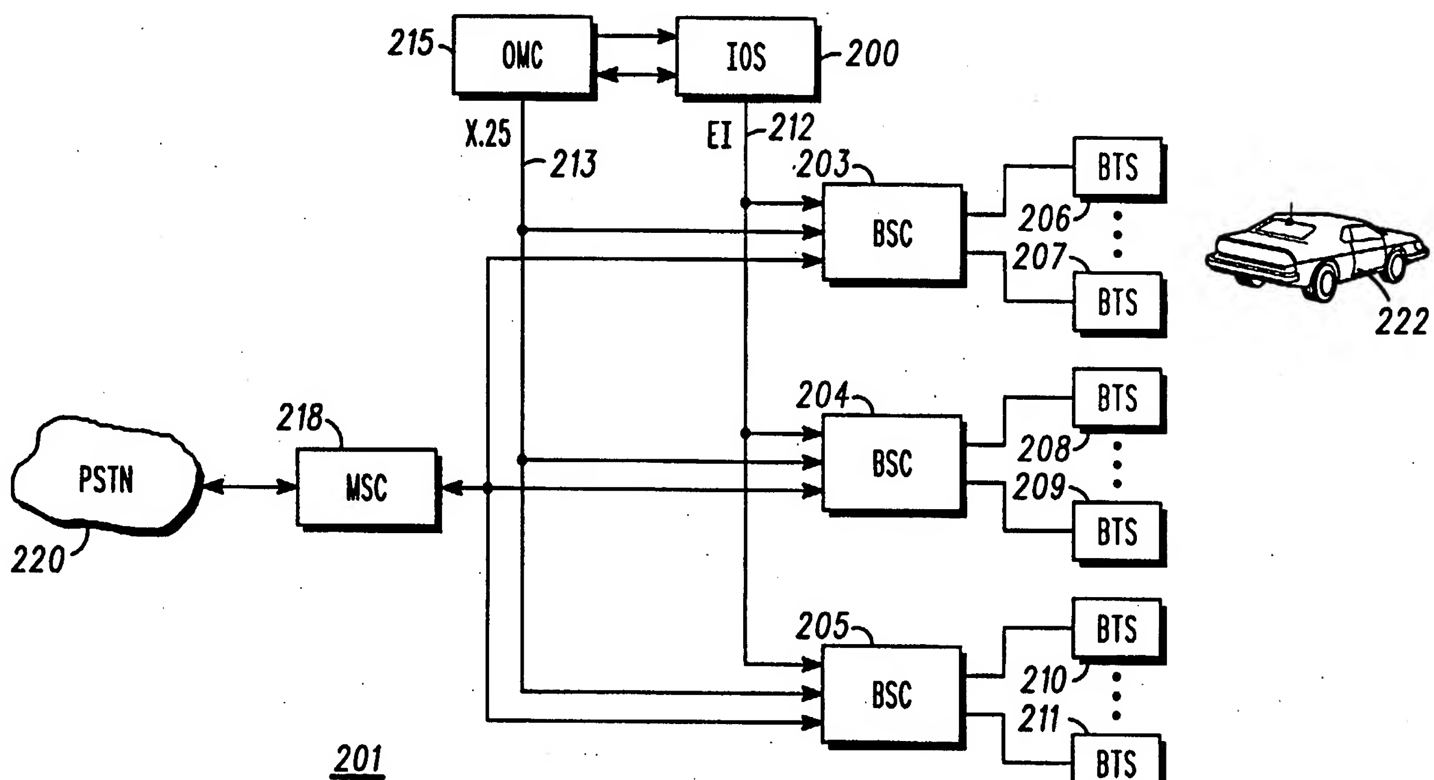

OMC
IOS
215
200
X.25
213
EI
212
203
204
205
BSC
BSC
BSC
BTS
BTS
BTS
BTS
BTS
BTS
206
207
208
209
210
211
222
PSTN
220
MSC
218
201

FIG. 2

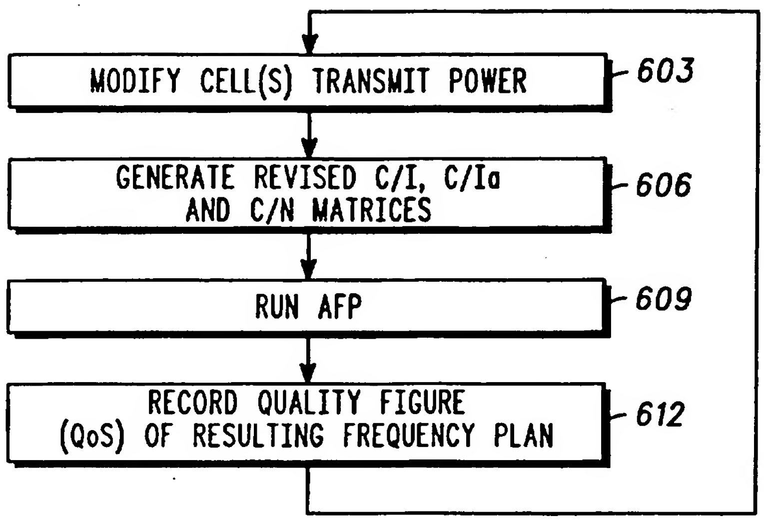


FIG. 6

	A1	A2	B	C1	C2	D
A1			7.5	2.5	2.5	5
A2			7.5	2.5	2.5	5
B	10	10		4	4	8
C1	2.5	2.5	10			8.5
C2	2.5	2.5	10			8.5
D	7	7	20	5	5	

FIG. 7

	A1	A2	B	C1	C2	D
A1			12	4	2	8
A2			3	1	0.5	2
B	10	4		4	2	8
C1	1	1.6	16			13
C2	4	0.4	4			4
D	7	3	20	5	2.5	

FIG. 8

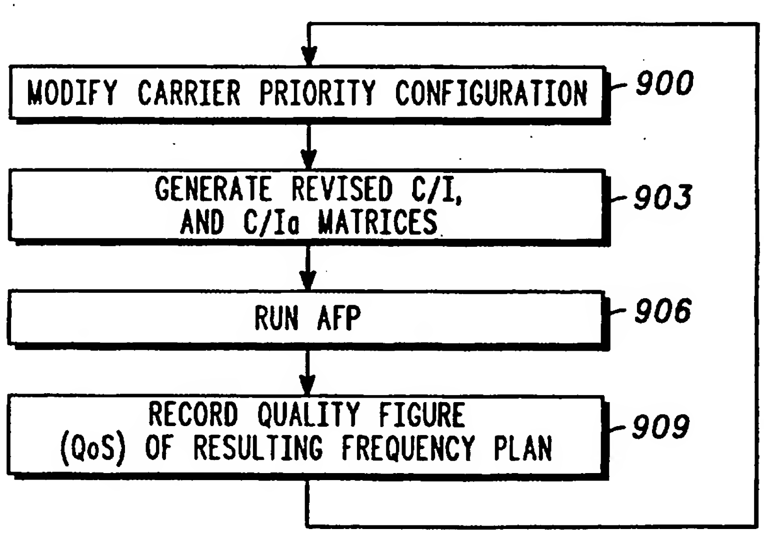


FIG. 9

JC17 Rec'd PCT/PTO 28 APR 2005

METHOD AND APPARATUS FOR DETERMINING A QUALITY OF A FREQUENCY REUSE PLAN IN A COMMUNICATION SYSTEM

FIELD OF THE INVENTION

The present invention relates, in general, to communication systems and, more particularly, to frequency reuse plans in such communication systems.

BACKGROUND OF THE INVENTION

The basic concept of system optimization is that measurement reports are collected from an operational network, and the data collected is then analyzed to generate an ideal frequency plan and neighbour cell list. An intermediate step in this process is the development of carrier-to-interference (C/I) matrices which indicate the degree of interference which would occur between pairs of cells in the network if they were to operate with co-channel or adjacent channel frequencies. Such a system which checks for any/all interference between any/all pairs of mobiles and any/all base stations in the system is described in U.S. Patent 4,736,453 to Schloemer. U.S. Patent 4,736,453 uses a matrix to display such results as is well known in the art.

A simplified example of a C/I matrix is shown in FIG. 1. As seen in FIG. 1, the entries in the matrix indicate the relative impact, defined herein as a penalty value, if any pairs of the cells A-D have co-channel frequencies. For example, the relative impact on cell A if cell C is made co-channel would be "5," where the "5" represents the percentage proportion of measurement reports which indicate that the received signal strength of a neighbour cell is greater than, for example, 15 dB below the serving cell signal level. Thus 5% of the measurement reports collected in cell A report cell C as being stronger than 15 dB below the level of cell A.

One problem with the current method of system optimization is that the values in the matrix have little to do with system quality. While it is generally well known that a smaller penalty value results in less interference between chosen carrier frequencies, there is currently no way to correlate the penalty value with an improvement in system quality. Thus, a need exists for an improved method and

apparatus for optimizing a communication system which overcomes the deficiencies of the prior art.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 generally depicts a frequency plan which depicts penalty values which is well known in the prior art.

FIG. 2 generally depicts a communication system which implements an improved intelligent optimization system (IOS) in accordance with the invention.

FIG. 3 generally depicts a plot of interference probability versus receive level of frequencies analyzed for common frequency interference in accordance with the invention.

FIG. 4 generally depicts a plot of interference probability versus receive level of frequencies analyzed for adjacent frequency interference in accordance with the invention.

FIG. 5 generally depicts a plot of interference probability versus receive level of frequencies analyzed for noise interference in accordance with the invention.

FIG. 6 generally depicts the process of updating the network QOS based on a change in transmit power of a cell in accordance with the invention.

FIG. 7 generally depicts a typical C/I matrix for a communication system incorporating multiple carrier frequencies per cell.

FIG. 8 generally depicts a C/I matrix for a communication system which has benefited from carrier priority in accordance with the invention.

FIG. 9 generally depicts the process of updating the network QOS based on a change in carrier priority in accordance with the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Stated generally, a communication system (201) implements an intelligent optimization system (IOS) block (200) to improve system quality in accordance with the invention. Measurement reports performed by a mobile station (222) are transferred to the IOS block (200) via the E1 links (212) as is configuration

information in the form of C/I values from an operations and maintenance center (OMC 215). This information is used by the IOS block (200) to determine a frequency reuse plan using at least one penalty value. The frequency reuse plan has associated therewith a quality factor (QOS) related to a proportion of estimated communication system traffic which is expected to experience poor quality due to the determined frequency reuse plan. If the frequency reuse plan is acceptable, the IOS block (200) passes relevant information to the OMC (215) which implements the plan.

Stated more specifically, a method for determining a quality of a frequency reuse plan in a communication system is disclosed. The communication system uses frequencies within cells of the communication system and the method includes the steps of analyzing a frequency for potential interference within a cell of the communication system and associating at least one penalty value to such frequency's potential use based on the step of analyzing. The method also includes the step determining a frequency reuse plan using the at least one penalty value, wherein the frequency reuse plan has associated therewith a quality factor related to a proportion of estimated communication system traffic which is expected to experience poor quality due to the determined frequency reuse plan.

In the preferred embodiment, the step of analyzing a frequency further comprises the step of analyzing a frequency with regard to common and adjacent frequency interference. The step of associating at least one penalty value to such frequency's potential use based on the step of analyzing further comprises the step of associating a carrier-to-interference (C/I) penalty value related to common and adjacent frequency interference and noise interference. Also, network characteristics are adjusted based on the quality factor associated with the determined frequency reuse plan, and the network characteristics comprise a power level of a carrier at the analyzed frequency and the assignment of a carrier frequency in cells having a plurality of carriers.

A system for determining a quality of a frequency reuse plan in a communication system is also disclosed. The system includes an optimization system for analyzing a frequency for potential interference within a cell of the communication system and for associating at least one penalty value to such frequency's potential use based on the analysis and an operations and maintenance center (OMC) for determining a frequency reuse plan using the at least one penalty value, wherein the frequency reuse plan has associated therewith a quality factor

related to a proportion of estimated communication system traffic which is expected to experience poor quality due to the determined frequency reuse plan. The optimization system implements measurement reports to analyze the frequency for potential interference within the cell of the communication system, where the measurement reports are performed by a mobile station within the communication system. The optimization system also implements carrier-to-interference (C/I) configuration information from the OMC to analyze the frequency for potential interference within the cell of the communication system.

FIG. 2 generally depicts the communication system 201 which implements an improved intelligent optimization system (IOS) in accordance with the invention. As shown in FIG. 2, the IOS block 200 is coupled to base-station controllers (BSCs) 203-205. In the preferred embodiment, E1 links 212 are used to perform the coupling, but one skilled in the art will recognize that any suitable link can be used. Each BSC 203-205 is coupled to a plurality of base transceiver stations (BTSs) 206-211 and are also coupled to an operations and maintenance center (OMC) 215 via a series of X.25 links 215 as is well known in the art. The OMC 215 and the IOS 200 are coupled to one another via a data transfer protocol. One skilled in the art will recognize that any type of data transfer protocol could be beneficially implemented. Finally, a mobile switching center (MSC) couples the BSCs 203-205 to the public switched telephone network (PSTN) 220.

In the preferred embodiment, the communication system 201 depicted in FIG. 2 is a time-division multiple access (TDMA) communication system 201 based on the Pan European Group Special Mobile (GSM) TDMA communication system. As one skilled in the art will appreciate, the inventive concept described herein can be implemented on other types of systems as well. Within the GSM communication system 201, a mobile station (MS) 222 constantly measures the signal strength of not only the serving base-station but also of neighbouring base-stations which transmit a signal strong enough to be received. These measurement values are transferred to the IOS block 200 via the E1 links 212 as is configuration information in the form of C/I values from the OMC 215. This information is used by the IOS block 200 to perform system optimization in accordance with the invention and to be described herein below. Once the IOS block 200 completes the system optimization, the relevant information is transferred to the OMC 215 which implements the system optimization as so determined by the IOS block 200 in accordance with the invention. It is envisioned that system optimization in

accordance with the invention should be performed when the system is initially installed, however one skilled in the art will appreciate that an operator could optimize the system as often as required.

In accordance with the invention, the penalty values for each cell/neighbour pair are calculated using the volume of traffic affected and the expected impact of an interfering signal to reflect the impact on the system quality of service (QOS) in accordance with the invention. In the preferred embodiment, the following equation is used:

$$CPenaltyValue(S,N) = AverageCarriedTraffic(S) \times \frac{\sum_{MRs(S)} MRcpv(N)}{TotalNoMRs(S)} \quad (1)$$

which reflects the volume of traffic disrupted if channel assignments in the serving cell S and a neighbour cell N are on co-channel frequencies. The *AverageCarrierTraffic(S)* is the mean traffic level of the serving cell S in Erlangs, the *TotalNoMRs(S)* is the number of measurement reports collected for serving cell S, *MRs(S)* is the set of all measurement reports collected from serving cell S and *MRcpv(N)* is the probability of signal disruption of serving cell S if neighbour cell N is received at the level indicated in the measurement report.

To aid in assigning meaning to the penalty value, *MRcpv(N)* or the probability of signal disruption of serving cell S if neighbour cell N is received at the level indicated in the measurement report can be plotted versus the difference in receive levels (Rxlev) for the serving cell (Rxlev(S)) and a neighbour cell (Rxlev(N)). Such a probability plot is shown in FIG. 3, which indicates that when the serving signal strength is significantly greater than the co-channel neighbour signal strength, the probability of signal disruption is low but gradually degrades as the difference between signal levels decreases. The plot shown in FIG. 3 indicates the preferred embodiment; one skilled in the art will recognize that other plots, or mappings, are possible.

In the preferred embodiment, the following equation is used to reflect the volume of traffic disrupted if channel assignments in the serving cell S and a neighbour cell N are on adjacent frequencies:

$$APenaltyValue(S,N) = AverageCarriedTraffic(S) \times \frac{\sum_{MRs(S)} MRapv(N)}{TotalNoMRs(S)} \qquad (2)$$

where *AverageCarriedTraffic(S)* is the mean traffic level of serving cell S in Erlangs, *TotalNoMRs(S)* is the number of measurement reports collected for serving cell S, *MRs(S)* is the set of all measurement reports collected from serving cell S and *MRapv(N)* is the probability of signal disruption of S if N is received at the level indicated in the measurement report. FIG. 4 depicts a probability plot which indicates that when the adjacent channel neighbour signal level is significantly greater than the serving signal level, the probability of disruption is high, but gradually improves as the difference between signal levels decreases. The plot shown in FIG. 4 indicates the preferred embodiment; one skilled in the art will recognize that other plots, or mappings, are possible. As is clear from FIG. 4, for the adjacent channel case, the signal only begins to degrade once the neighbour cell is stronger than the serving cell; then as the difference increases (i.e., the neighbour cell gets even stronger), the probability of disruption increases.

As can be understood, the C/I matrix values can be calculated for all cell pairs and the automatic frequency planning (AFP) tool located in the OMC 215 can then select the frequency plan which minimizes the total penalty value. As such, the total penalty value of a specific frequency plan will then represent the total traffic volume which can be expected to be disrupted due to interference in accordance with the invention.

Another important factor which can cause signal disruption is low signal level with respect to system noise, identified as C/N. To accurately predict network QOS, the C/N must be considered. The volume of a cells' traffic which will be disrupted due to low C/N will be independent of the frequency plan and can be calculated from the measurement report data using the following equation:

$$NPenaltyValue(S) = AverageCarriedTraffic(S) \times \frac{\sum_{MRs(S)} MRnpv}{TotalNoMRs(S)} \qquad (3)$$

where *AverageCarriedTraffic(S)* is the mean traffic level of serving cell S, in Erlangs, *TotalNoMRs(S)* is the number of measurement reports collected for

serving cell S, *MRs(S)* is the set of all measurement reports collected from serving cell S and *MRnpv* is the probability of signal disruption of serving cell S if the noise in serving cell S is received at the level indicated in the measurement report. FIG. 5 depicts a probability plot which indicates again that when the receive signal level is high, the probability of signal disruption is low but gradually degrades as the receive signal levels decreases. Again, the plot shown in FIG. 5 indicates the preferred embodiment; one skilled in the art will recognize that other plots, or mappings, are possible.

The predicted measure of network QOS for a given frequency plan, identified as QOS(FP), can then be calculated from the total penalty value of that frequency plan together with the C/N penalty values from each cell using the equation:

$$QOS(FP) = {(TotalPenaltyValue(FP) + \sum_{S} NPenaltyValue(S))} \Big/ {AverageCarriedTraffic} \qquad (4)$$

where *AverageCarriedTraffic* is the mean traffic volume carried by the network in Erlangs. QOS(FP) thus represents the proportion of total traffic which is expected to experience poor quality due to the proposed radio plan, and as such is a powerful measure of network QOS. Also, it can be expected to be proportional to other quality measures such as drop call rate and call success rate.

With this new method and apparatus for quantifying network QOS, many other system improvements can be realised. For example, by now adjusting the underlying network characteristics, the C/I, C/Ia and C/N matrices can be adjusted to allow a higher quality frequency plan to be developed. This would enable an operator to improve network QOS and/or capacity in accordance with the invention.

One such network characteristic which could be made to improve network QOS is to change the transmit power of a cell. After making such a change, new matrices can easily be calculated based on the proposed revised power levels. The AFP can then determine if a higher quality frequency plan solution would exist after making such a change using the QOS quantifying techniques described above in accordance with the invention.

FIG. 6 generally depicts the process of updating the network QOS based on a change in transmit power of a cell in accordance with the invention. It is noted that in the preferred embodiment, this process would be an iterative process which would repeat multiple times based on requirements of the operator. The input variables are the individual transmit power levels of the network cells, and the output variable, which should be minimized, is the network quality figure QOS as described above. Many techniques exist for searching for an optimum setting of multiple input variables; for example, simulated annealing or an equivalent method could be beneficially selected to drive this process.

As shown in FIG. 6, the process starts at step 603 where the cell's transmit power is modified. The transmit power setting for each cell within the network represents the input variables to this process. These should be changed according to the algorithm selected. Next, at step 606, new C/I, C/Ia and C/N matrices are generated based upon the new cell transmit powers selected. The algorithm used is the same as described above, but the values of receive levels of all cells must be adjusted by the offset in their respective transmit powers. A revised algorithm for calculating C/I is provided below using the equation:

$$CPenaltyValue(S,N) = AverageCarriedTraffic(S) \times \frac{\sum_{MRs(S)} MRcpv(N)}{TotalNoMRs(S)} \tag{5}$$

where *AverageCarriedTraffic(S)* is the mean traffic level of serving cell S in Erlangs, *TotalNoMRs(S)* is the number of measurement reports collected for serving cell S, *MRs(S)* is the set of all measurement reports collected from serving cell S and *MRcpv(N)* is the probability of signal disruption of S if N is received at the level indicated in the measurement report. The receive levels of S and N must be offset by any change in the cells transmit power, *Spo* and *Npo* respectively. A positive *Spo* and/or *Npo* represents a power reduction to S and N respectively, measured in dB.

A revised algorithm for calculating C/Ia is provided below using the equation:

$$APenaltyValue(S,N) = AverageCarriedTraffic(S) \times \frac{\sum_{MRs(S)} MRapv(N)}{TotalNoMRs(S)}$$

(6)

where *AverageCarriedTraffic(S)* is the mean traffic level of serving cell S in Erlangs, *TotalNoMRs(S)* is the number of measurement reports collected for serving cell S, *MRs(S)* is the set of all measurement reports collected from serving cell S, *MRapv(N)* is the probability of signal disruption of S if N is received at the level indicated in the measurement report. The receive levels of S and N must be offset by any change in the cells transmit power, *Spo* and *Npo* respectively. Positive *Spo* and/or *Npo* represent power reduction to S and N respectively, measured in dB.

The algorithms for calculating the C/N penalty value is given below in the following equation:

$$NPenaltyValue(S) = AverageCarriedTraffic(S) \times \frac{\sum_{MRs(S)} MRnpv}{TotalNoMRs(S)}$$

(7)

where *AverageCarriedTraffic(S)* is the mean traffic level of serving cell S in Erlangs, *TotalNoMRs(S)* is the number of measurement reports collected for serving cell S, *MRs(S)* is the set of all measurement reports collected from serving cell S and *MRnpv* is the probability of signal disruption of S if S is received at the level indicated in the measurement report. The receive level of S must be offset by any change in the cell transmit power, *Spo*. A positive *Spo* represents power reduction to S, measured in dB.

At step 609, the AFP operates as normal to identify the frequency plan which provides the best network quality, based on the revised C/I, C/Ia and C/N matrices. Next, at step 612, the quality figure (QOS) of the resulting frequency plan is recorded. It is most important that this includes the C/N penalty value also, since any reduction in cell transmit power is certain to increase its C/N penalty value. The quality factor QOS is generated in IOS block 200 and provided to OMC 215 for system implementation. In this embodiment, the algorithm for calculating the quality factor QOS is as shown in equation (4) above.

Note that in order for this process to be valid, the handover boundaries between cells must remain constant when the new frequency plan and transmit powers are implemented. Power budget algorithms existing in GSM

communication systems already compensate for BTS/MS maximum transmit power, such that no parameter changes should be necessary.

Until this point, the discussion of the C/I matrix has assumed single carrier cells. In reality, however, multi-carrier cells must also be considered. Assuming that cells A and C are given an extra carrier, then the C/I matrix would become that as shown in FIG. 7. With traditional channel assignment algorithms, traffic tends to be distributed evenly across the carriers of a cell. As such, the volume of traffic affected if cell B is co-channel to a carrier of cell A will be 7.5 per carrier, rather than 15 as shown in FIG. 1 which would have been impacted if cell A were a single carrier cell.

To deliver an optimum frequency plan, elements within the matrix must reflect the amount of traffic which would be impacted if the respective carriers were co-channel. The C/I and C/Ia matrices are developed from monitoring the Broadcast Control Channel (BCCH) carriers, which are always on, and at full power, and it is assumed that traffic loading is evenly spread across a cell's carriers. This leads to two sources of inaccuracies. First, the second carrier in a cell, C2 for example in FIG. 7, will not always be transmitting, and not necessarily at full power. Thus the amount of traffic in cell A impacted if carrier C2 is co-channel would actually be less than the value of 2.5. How much less depends on how often C2 is transmitting, which will vary with the time of day, etc. Second, traffic will not necessarily be evenly distributed across the carriers in a cell. This will depend on the channel assignment scheme.

In accordance with the invention, the C/I and C/Ia matrices generation is modified to reflect the respective traffic loads on each carrier and the probability that a particular carrier is transmitting. Stated differently, the inventive feature can be used to develop a frequency plan that is optimised for non-uniform distribution of traffic within a cell. An algorithm to calculate a revised C/I matrix is given below using following equation:

$$CPenaltyValue(Sx, Nx) = AverageCarriedTraffic(Sx) \times \frac{\sum\limits_{MRs(S)} \left(\sum\limits_{p} \left(MRcpv(N, p) \times Pp(Nx) \right) \right) \times Pt(Nx)}{TotalNoMRs(S)} \qquad (8)$$

where *Sx* and *Nx* are specific carriers of serving and neighbour cells S and N and each represents a specific matrix element, *AverageCarriedTraffic(Sx)* is the mean traffic level of carrier *Sx*, in Erlangs, *TotalNoMRs(S)* is the number of measurement reports collected for serving cell S, *MRs(S)* is the set of all measurement reports collected from serving cell S, *Pp(Nx)* is the probability that carrier *Nx* will transmit with a power level reduction of *p* dB, *Pt(Nx)* is the probability that *Nx* is transmitting and *MRcpv(N,p)* is the probability of signal disruption of S if N is received at the level indicated in the measurement report reduced by power *p*.

The probability of *Nx* transmitting, *Pt(Nx)*, and the traffic load of *Sx*, *AverageCarriedTraffic(Sx)* will vary with time of day/week, creating non-linear dependencies. Therefore, to get a fully accurate C/I matrix, separate C/I matrices can be developed for each distinctive time period, and these then averaged to generate an overall C/I matrix. However, to simplify the procedure, the busy hour value of *Pt(Nx)* could be used in conjunction with *AverageCarriedTraffic(Sx)* which would then remove the need for time dependent C/I matrix generation, with only a small loss of quality.

An algorithm to calculate a revised C/Ia matrix is given below using the following equation:

$$APenaltyValue(Sx,Nx) = AverageCarriedTraffic(Sx) \times \frac{\sum\limits_{MRs(S)} \left(\sum\limits_{p} \big(MRapv(N,p) \times Pp(Nx) \big) \right) \times Pt(Nx)}{TotalNoMRs(S)} \quad (9)$$

where *Sx* and *Nx* are specific carriers of serving and neighbour cells S and N and each represents a specific matrix element, *AverageCarriedTraffic(Sx)* is the mean traffic level of carrier *Sx* in Erlangs, *TotalNoMRs(S)* is the number of measurement reports collected for serving cell S, *MRs(S)* is the set of all measurement reports collected from serving cell S, *Pp(Nx)* is the probability that carrier *Nx* will transmit with a power level reduction of p dB, *Pt(Nx)* is the probability that *Nx* is transmitting and *MRapv(N,p)* is the probability of signal disruption in S due to adjacent channel interference if N is received at the level indicated in the measurement report reduced by power *p* (in dB).

The probability of *Nx* transmitting, *Pt(Nx)*, and the traffic load of *Sx*, *AverageCarriedTraffic(Sx)* will vary with the time of day and/or week, again creating non-linear dependencies. Therefore, as with the C/I matrices, to get a fully accurate C/Ia matrix, separate C/Ia matrices should be developed for each distinctive time period, and these separate C/Ia matrices should be averaged to generate an overall C/Ia matrix. Again, to simplify the procedure, the busy hour value of *Pt(Nx)* could be used in conjunction with the *AverageCarriedTraffic(Sx)* which would remove the need for time dependent C/Ia matrix generation with a small loss of quality.

A process to achieve carrier priority in accordance with the invention is depicted in FIG. 9. It is envisaged that the process of FIG. 9 would be an iterative process which would repeat multiple times based on requirements of the communication system 201 operator. The input variables in the process are the carrier priority settings of the network cells while the output variable, which is to be minimized, is the network quality figure or QOS. As one skilled in the art will appreciate, many techniques exist for searching for an optimum setting of multiple input variables, including simulated annealing.

Referring to FIG. 9, the process starts at step 900 when the carrier priority settings associated with each cell within the network are changed according to the algorithm selected. Next, at step 903, new C/I and C/Ia matrices are generated based upon the new carrier priority settings as noted above with respect to equations (8) and (9). The effect of the carrier priority setting on the input variables *AverageCarriedTraffic(Sx)* and *Pt(Nx)* can be readily calculated using the Erlang-B table as one skilled in the art will appreciate. The AFP is then run at step 906 as normal to identify the frequency plan which provides the best network quality QOS based on the revised C/I and C/Ia matrices generated at step 903. The quality figure (QOS) of the resulting frequency plan is recorded. at step 909 and provided by IOS block 200 to OMC 215 for implementation in the communication system 201 shown in FIG. 2. The algorithm for calculating the quality figure (QOS) is shown in equation (4) above.

Implementing the above described carrier priority scheme on the matrix shown in FIG. 7, which generally depicts a prior art matrix, could result in, as an example, the matrix shown in FIG. 8. From the matrix depicted in FIG. 7, it can be seen that any cell C carrier (C1,C2) interfering with a cell A carrier (A1,A2) will have an equal impact, affecting about 2.5% of traffic in each case. However,

with the revised matrix depicted in FIG. 8 in accordance with the invention, the impact of making carrier C2 co-channel with carrier A2 will only impact 0.5% of traffic due to the fact that carrier A2 carries relatively little traffic now, and carrier C2 is not transmitting for a significant proportion of the time. It will be understood by those skilled in the art that a matrix which indicates widely differing penalty values can lead to a higher quality solution than a matrix with more similar values, even if the overall mean value is constant. Thus, the matrix depicted in FIG. 8 allows the generation of a higher quality frequency plan in accordance with the invention.

While the invention has been particularly shown and described with reference to a particular embodiment, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention. The corresponding structures, materials, acts and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or acts for performing the functions in combination with other claimed elements as specifically claimed.

What we claim is:

CLAIMS

1. A method for determining a quality of a frequency reuse plan in a communication system, the communication system using frequencies within cells of the communication system, the method comprising the steps of:

analyzing a frequency for potential interference within a cell of the communication system;

associating at least one penalty value to such frequency's potential use based on the step of analyzing;

determining a frequency reuse plan using the at least one penalty value, wherein the frequency reuse plan has associated therewith a quality factor related to a proportion of estimated communication system traffic which is expected to experience poor quality due to the determined frequency reuse plan.

2. The method of claim 1, wherein the step of analyzing a frequency further comprises the step of analyzing a frequency with regard to common and adjacent frequency interference.

3. The method of claim 2, wherein the step of associating at least one penalty value to such frequency's potential use based on the step of analyzing further comprises the step of associating a carrier-to-interference (C/I) penalty value related to common and adjacent frequency interference and noise interference.

4. The method of claim 3, wherein the penalty value related to common frequency interference is given by the equation

$$CPenaltyValue(S,N) = AverageCarriedTraffic(S) \times \frac{\sum_{MRs(S)} MRcpv(N)}{TotalNoMRs(S)}$$

where *AverageCarrierTraffic(S)* is a mean traffic level of a serving cell S in Erlangs, the *TotalNoMRs(S)* is a number of measurement reports collected for serving cell S, *MRs(S)* is the set of all measurement reports collected from serving

cell S and *MRcpv(N)* is the probability of signal disruption of serving cell S if a neighbour cell N is received at the level indicated in the measurement report.

5. The method of claim 4, wherein the penalty value related to adjacent frequency interference is given by the equation

$$APenaltyValue(S,N) = AverageCarriedTraffic(S) \times \frac{\sum_{MRs(S)} MRapv(N)}{TotalNoMRs(S)}$$

where *AverageCarriedTraffic(S)* is a mean traffic level of a serving cell S in Erlangs, *TotalNoMRs(S)* is a number of measurement reports collected for serving cell S, *MRs(S)* is the set of all measurement reports collected from serving cell S and *MRapv(N)* is the probability of signal disruption of serving cell S if a neighbour cell N is received at the level indicated in the measurement report.

6. The method of claim 5, wherein the penalty value related to noise interference is given by the equation

$$NPenaltyValue(S) = AverageCarriedTraffic(S) \times \frac{\sum_{MRs(S)} MRnpv}{TotalNoMRs(S)}$$

where *AverageCarriedTraffic(S)* is a mean traffic level of a serving cell S, in Erlangs, *TotalNoMRs(S)* is a number of measurement reports collected for serving cell S, *MRs(S)* is the set of all measurement reports collected from serving cell S and *MRnpv* is the probability of signal disruption of serving cell S if the noise in serving cell S is received at the level indicated in the measurement report.

7. The method of claim 6, wherein the quality factor related to a proportion of estimated communication system traffic which is expected to experience poor quality due to the determined frequency reuse plan

$$QOS(FP) = {}^{(TotalPenaltyValue(FP) + \sum_{S} NPenaltyValue(S))} \Big/ {}_{AverageCarriedTraffic}$$

where *AverageCarriedTraffic* is a mean traffic volume carried by the network in Erlangs.

8. The method of claim 1, wherein network characteristics are adjusted based on the quality factor associated with the determined frequency reuse plan.

9. The method of claim 8, wherein the network characteristics comprise a power level of a carrier at the analyzed frequency and the assignment of a carrier frequency in cells having a plurality of carriers.

10. A system for determining a quality of a frequency reuse plan in a communication system, the communication system using frequencies within cells of the communication system, the system comprising:

an optimization system for analyzing a frequency for potential interference within a cell of the communication system and for associating at least one penalty value to such frequency's potential use based on the analysis; and

an operations and maintenance center (OMC) for determining a frequency reuse plan using the at least one penalty value, wherein the frequency reuse plan has associated therewith a quality factor related to a proportion of estimated communication system traffic which is expected to experience poor quality due to the determined frequency reuse plan.

11. The system of claim 10, wherein the optimization system implements measurement reports to analyze the frequency for potential interference within the cell of the communication system.

12. The system of claim 11, wherein the measurement reports are performed by a mobile station within the communication system.

13. The system of claim 10, wherein the optimization system implements carrier-to-interference (C/I) configuration information from the OMC to analyze the frequency for potential interference within the cell of the communication system.

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Application No:	GB 9926513.4	**Examiner:**	John Betts
Claims searched:	1-13	**Date of search:**	9 May 2000

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Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): H4L (LDSE, LDTR, LDTX, LFMA)

Int Cl (Ed.7): H04Q 3/00, 7/34, 7/36,17/00) H04B (1/10 17/00 H04L (12/28, 12/24)

Other: On-line: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB2327014 A	(Ericsson)	
A	GB2313264 A	(Harris Corp)	
A	US5293640	(Televerket)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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